RCA PF030002 PD

CITED BY APPLICANT

(12) UK Patent Application (19) GB (11) 2 282 286 (13) A

(43) Date of A Publication 29.03.1995

(21) Application No 9317317.7

(22) Date of Filing 20.08.1993

(71) Applicant(s)
Motorola Inc

(Incorporated in USA - Delaware)

Corporate Offices, 1303 East Algonquin Road, Schaumburg, Illinois 60196, United States of America

(72) Inventor(s)
Ilan Horowitz
Moshe Ben-Ayun
Eliezer Fogel

(74) Agent and/or Address for Service
Hugh Christopher Dunlop
Motorola Limited, European Intellectual Property Operation, Jays Close, Viables Industrial Estate, BASINGSTOKE, Hampshire, RG22 4PD, United Kingdom

(51) INT CL[6]
H04B 1/00 // H03D 7/00 , H04L 27/34

(52) UK CL (Edition N)
H3R RMA
H4P PAQ
U1S S2204 S2205

(56) Documents Cited
EP 0540195 A2 **US 4893316 A**

(58) Field of Search
UK CL (Edition L) **H3R RADC RADX RAMX RMA RMX, H4P PAQ**
INT CL[5] **H03D , H04L**
Online databases: WPI, EDOC

(54) A radio device with spectral inversion

(57) A radio device, such as a radio receiver or a radio transmitter, is described comprising a radio stage (30) and a baseband stage (36), where the baseband stage comprises a digital signal processor arranged (40) to invert the spectral shape of a signal passing through the radio device, to compensate for spectral inversion of the signal between the radio stage and the baseband stage. The arrangement is particularly applicable to reception or transmission of signals modulated according to a modulation scheme having an asymmetric spectral shape, such as QAM. The digital signal processor (40) computes the complex conjugate product of a signal, effectively inverting its spectral shape. A crystal filter 32 removes unwanted image signal components.

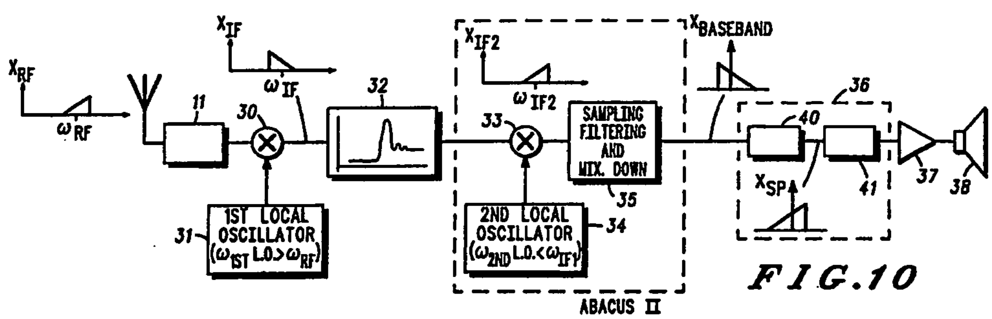
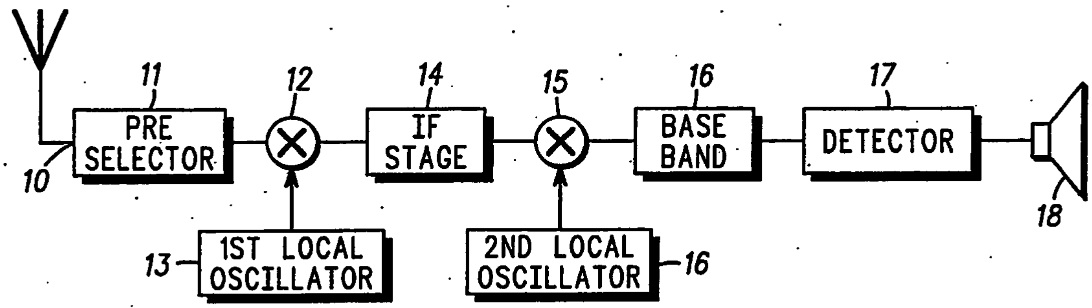


FIG.10

GB 2 282 286 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.



— PRIOR ART —

FIG.1

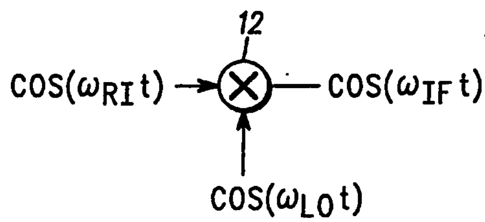


FIG.2

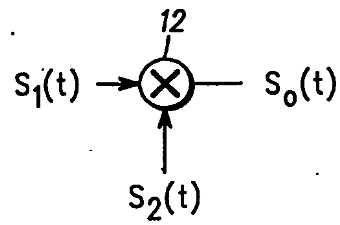


FIG.3

FIG.5

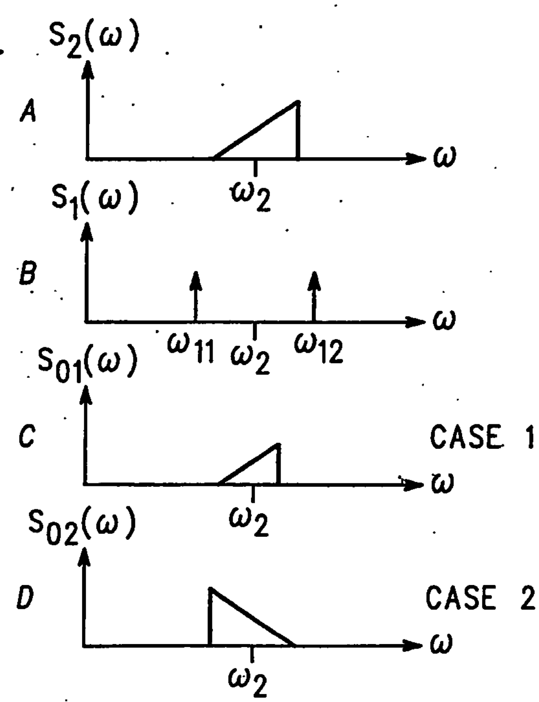


FIG.4

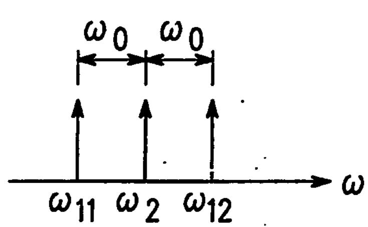


FIG.6

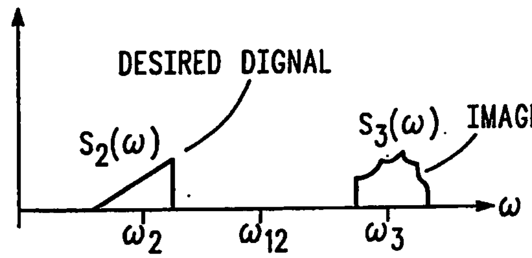


FIG.7

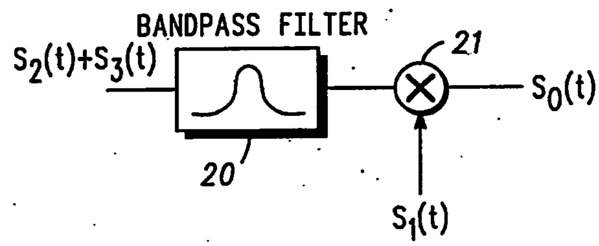
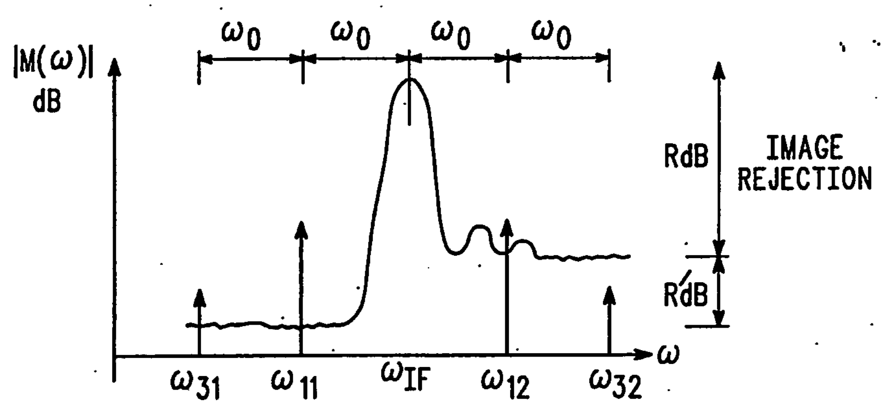


FIG.8



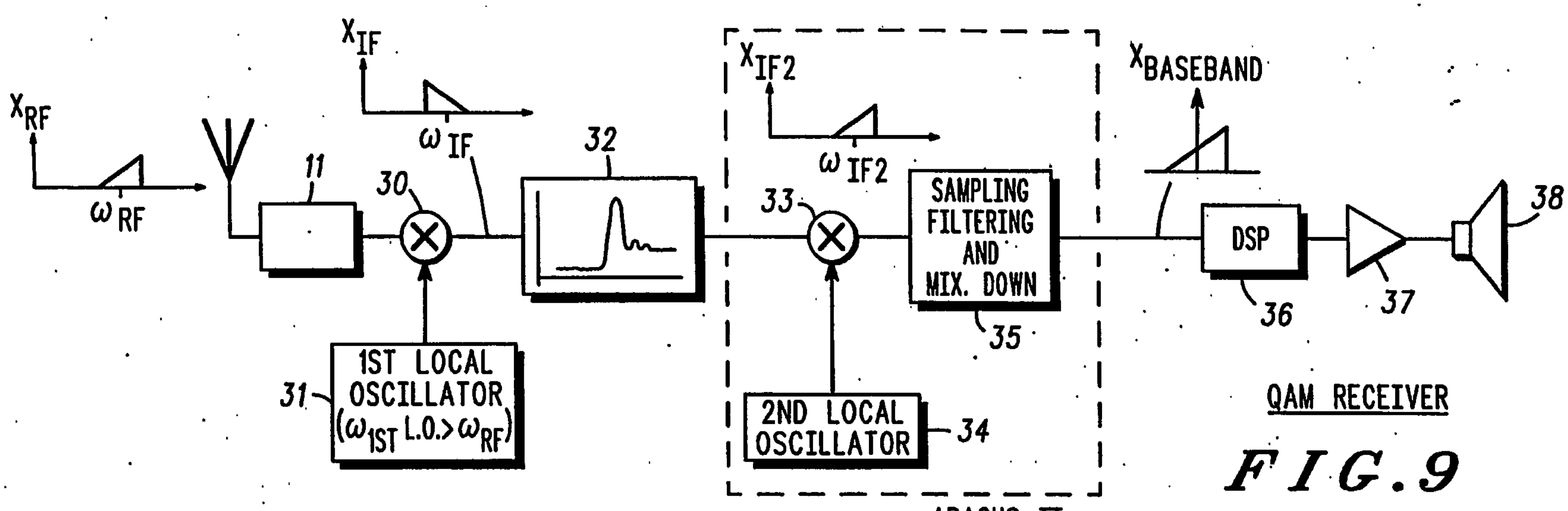


FIG.9
—PRIOR ART—

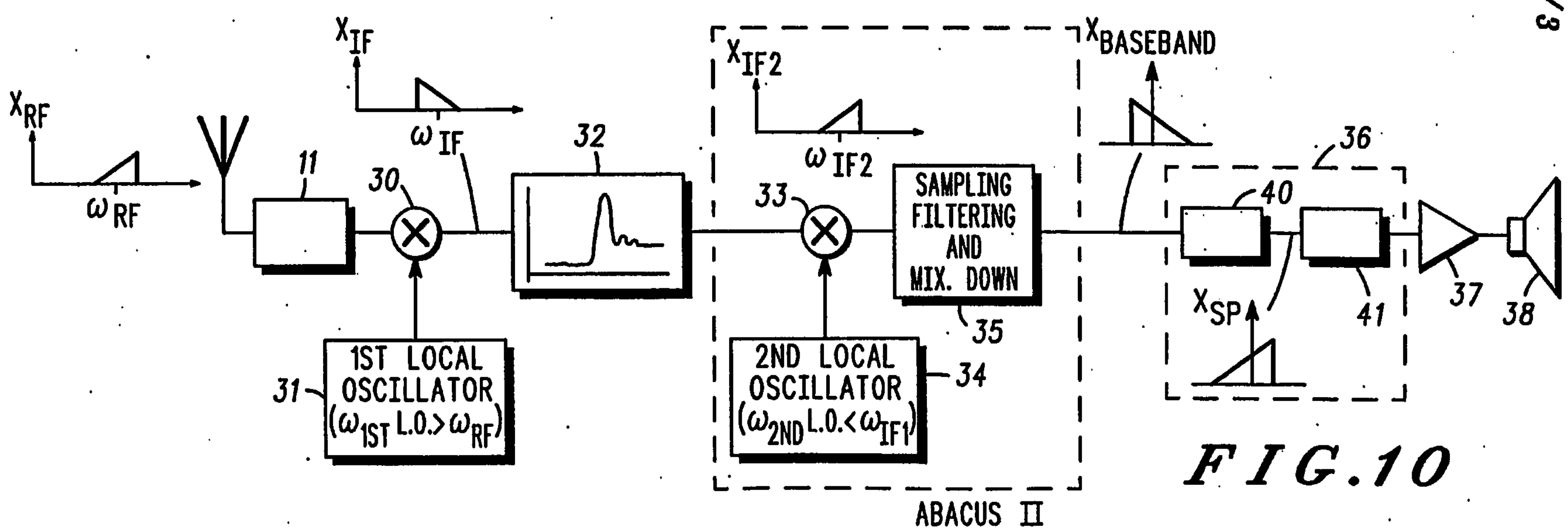


FIG.10

2282286

A RADIO DEVICE WITH SPECTRAL INVERSION

Field of the Invention

This invention relates to a radio device, such as a radio receiver or a radio transmitter. The invention is particularly applicable to reception or transmission of signals modulated according to a modulation scheme having an asymmetric spectral shape, such as QAM.

Background to the Invention

In a super heterodyne receiver the radio frequency (RF) signal is converted to an intermediate frequency (IF) and then to baseband. The baseband signal is demodulated and the information contained therein is transferred to a speaker or other output device. Sometimes more than one IF frequency is used in several stages of mixing.

When mixing an injection signal from a local oscillator into the signal path to provide a required IF signal, the local oscillator frequency can be selected to be below or above the desired IF frequency. When the local oscillator is below the desired frequency, it is referred to as "lower conversion" or "lower side injection" and when the local oscillator frequency is above the desired frequency, it is referred to as "upper conversion" or "upper side injection". Lower conversion maintains the spectral shape of the desired signal relative to DC. Upper conversion inverts the spectral shape of the desired signal. Inversion of the spectral shape is, for many modulation schemes, insignificant. In such cases, the radio designer is free to select lower conversion or upper conversion to achieve the best results depending upon the characteristics of the various elements (filters, preselectors etc) in the radio chain.

A problem arises when receiving or transmitting a signal which is modulated according to a modulation scheme that is not symmetric around DC. QAM and its variants (e.g. 16 QAM) is an example of a modulation that is not symmetric around DC. If the spectral shape of such a signal is inverted, the actual data carried by the signal appears to change. This places constraints upon the radio designer in that he cannot use an odd number of upper conversions in the chain, as this would lead to spectral inversion.

The present invention addresses this problem.

Summary of the Invention

According to the present invention, a radio device is provided comprising a radio stage and a baseband stage, where the baseband stage comprises a digital signal processor arranged to invert the spectral shape of a signal passing through the radio device, to compensate for spectral inversion of the signal between the radio stage and the baseband stage.

The radio device may be a heterodyne receiver having an intermediate frequency stage with a local oscillator and a mixer for injecting an injection signal from the local oscillator into the signal, where the frequency of the signal from the local oscillator is higher than the pass band of the filtered signal, thereby causing spectral inversion of the signal.

In this way, an odd number of spectral inversions between the radio stage and the baseband stage can be tolerated and can be employed to take advantage of the characteristics of elements between those stages, the odd number of spectral inversions being compensated by the digital signal processor (DSP).

The DSP is preferably arranged to compute the complex conjugate product of signal. The complex conjugate product of a signal has a spectral shape which is inverted with respect to the signal itself.

The invention is equally applicable to receivers and transmitters. In the case of a transmitter, if the transmitter chain causes spectral inversion of the signal, the DSP inverts the signal at the base band prior to outputting along the chain of transmitter stages.

Brief Description of the Drawings

Fig. 1 shows a typical prior art heterodyne radio receiver.

Figs. 2 and 3 show a mixer, for explanation of mixer theory.

Fig. 4 shows different injection signals in the frequency domain, for further explanation of mixer theory.

Fig. 5 illustrates the phenomenon of spectral inversion.

Fig. 6 illustrates a problem known as the image signal.

Fig. 7 shows a band pass filter and a mixer for explanation of optimisation of a mixer stage.

Fig. 8 shows a typical crystal filter characteristic.

Fig. 9 shows a prior art QAM receiver and

Fig. 10 shows a block diagram of a receiver in accordance with the present invention.

Detailed Description of the Drawings

Fig. 1 shows a typical super heterodyne receiver. It comprises an RF input 10, a preselector 11, a first mixer 12 having a first local oscillator 13, an IF stage 14, a second mixer 15 having a second local oscillator 16, a baseband stage 16, a demodulator 17 and an output in the form of a speaker 18.

The receiver RF signal input at the input 10 is converted to an IF frequency in mixer 12 and further converted to baseband in mixer 15. The baseband signal is demodulated and the information is output at the output 18.

In order to receive a certain required frequency, the first local oscillator 13 frequency is selected so that the mixing product of the RF and the local oscillator will be at the desired IF. This is illustrated in Fig. 2, where ω_{RF} signal, ω_{IF} is the IF signal and ω_{LO} is the local oscillator signal. Some receivers have more than one IF frequency in order to improve performance.

The frequency conversion is done by mixer 12. The mixer is forming a multiplication of two signals as shown in Fig. 3.

So(t) = S1(t)*S2(t)

assume: S1(t)=A1*cos ω1*t

S2(t)=A2*cos ω2*t

So(t)=A1*A2*cos(ω1*t)*cos(ω2*t)=1/2*A1*A2*(cos(ω1+ω2)t + cos(ω1-ω2)t)

From this it can be seen that two different frequencies are obtained at the mixer's output. In order to obtain a certain frequency ω_O at the mixer output, with ω2 being constant, the designer can choose one of two cases:

Case 1: ω11 + ω2 = ωO > ω11 = ωO-ω2

Case 2: ω12 - ω2 = ωO > ω12 = ωO + ω2

by choosing ω11 or ω12, ω_O is obtained at the mixer's output, as illustrated in Fig. 4.

When ω11 is used it is called lower conversion and when ω12 is used it is called upper conversion. Upper and lower are relative to ω2, which is the desired frequency.

Fig. 5 shows how a mixer converts a desired spectral shape, which is equivalent to a desired channel. Signal A shows, for illustrative purposes a desired signal which increases in magnitude with frequency centred around $\omega 2$. Either of the two signals labelled B can be used as the injection signal. These injection signals respectively give rise to signals C and D as illustrated.

$$\omega_{12} - \omega_2 + \omega_O = \omega_2 - \omega_{11}$$
$$S_{O1}(t) = S_2(t) \cos(\omega_{11}t)$$
$$S_{O2}(t) = S_2(t) \cos(\omega_{12}t)$$

It can be seen that while using lower side conversion (case 1) a spectral shape at ω_O is the same as at ω_2. While using the upper side conversion, the spectral shape at ω_O is upside-down relative to the spectral shape at ω_2.

It is normal therefore to design an RF receiver to convert it to baseband with no upper side conversions, or an even number of upper side conversions.

While using the mixer as a frequency converter, it has to be taken into account that when converting a desired signal, an undesired signal is also converted to the IF. This signal is called the image signal and is illustrated in Fig. 6.

In order to reduce the undesired signal level at the mixer's output, it is attenuated before the mixer. This is illustrated in Fig. 7, where a bandpass filter 20 is shown immediately prior to a mixer 21. The image rejection is equal to the amount of attenuation at the image frequency related to the attenuation at the desired frequency. Fig. 8 shows a characteristic of a typical IF crystal filter. If upper side conversion is used in the mixer of Fig. 7, an image rejection of RdB is achieved as shown.

Many receivers have two IF frequencies. Referring again to Fig. 1, the IF stage 14 can comprise a crystal filter followed by an additional mixer and local oscillator, followed by a bandpass filter. This additional mixer will be referred to as the second local oscillator. The desired resulting signal will be referred to as the second IF.

Such a receiver has two image frequencies, one caused by the first IF frequency and the other being caused by the second IF frequency. The first IF image rejection is achieved by the preselector attenuation at the image frequency and the second IF image rejection is achieved by the crystal filter attenuation at the second IF image frequency.

The second IF image rejection is limited by the crystal filter attenuation. As can be seen in Fig. 8, the natural response of a crystal filter is not symmetric around the passband frequency. The ultimate attenuation of the frequencies below the central frequency is higher than attenuation of the frequencies above the central frequency (by an amount R'dB). Due to this crystal filter nature, it is generally preferable to use lower side conversion as the second conversion in order to improve the second IF image rejection.

By contrast, it is frequently the case that a preselector 11 provides greater attenuation at frequencies above its centre frequency.

If, therefore, a preselector and a crystal filter are used to their optimum, there is an overall frequency spectrum inversion.

Simply providing a further mixer to achieve spectrum conversion is undesirable, due to insertion loss arising from additional stages.

A QAM signal is a complex signal such that the baseband spectral shape is not symmetric around DC. If upper side conversion is used in a first IF stage, upper side conversion should also be used in the second IF stage, to maintain the spectral shape. This is illustrated in Fig. 9. In this figure, there is shown a first mixer 30 with a first local oscillator 31, a crystal filter 32, a second mixer 33 with a second local oscillator 34, a sampler, filter and down mixer 35, a digital signal processor 36, a digital-to-analog converter 37 and an audio output 38. The elements 33, 34 and 35 are together provided by a device referred to as "Abacus II", which is .... .

At each stage in the apparatus, it is shown in the diagram whether the desired signal is above or below the first and second local oscillator signals and whether the desired signal is inverted or non-inverted. The resulting signal to the DSP 36 is non-inverted, so that the information is retained.

Referring now to Fig. 10, the same elements as are found in Fig. 9 are shown, except that in this case, the second local oscillator frequency from oscillator 34 is below the IF signal from filter 32, thereby giving lower side conversion and taking full advantage of the better image rejection on the lower side of the filter characteristic of filter 32. The signal to the DSP 36 is spectrally inverted.

DSP 36 re-inverts the spectral shape of the signal in complex conjugate inverter 40.

This inverter 40 is a simple software routine in DSP 36 which takes the complex conjugated product of the received data and inverts the spectral shape of the signal, as follows:

$$X(t) \xrightarrow{F} X(\omega)$$
$$X^*(t) \xrightarrow{F} X(-\omega)$$

The spectrally inverted data is passed to demodulator and decoder 41 for producing a digitized audio signal which is output at the speaker 38.

A QAM signal comprises in-phase (I) and quadrature (Q) samples, as is well known in the art. The inverter 40 simply reverses the sign of the Q samples, that is to say multiplies those samples by -1.

Claims

1. A radio device comprising a radio stage (30) and a baseband stage (36), where the baseband stage comprises a digital signal processor arranged (40) to invert the spectral shape of a signal passing through the radio device, to compensate for spectral inversion of the signal between the radio stage and the baseband stage.

2. A radio device according to claim 1, where the device is a heterodyne receiver and comprises a bandpass filter (32) coupled to receive a signal from the radio stage and an intermediate frequency stage having a local oscillator (34) and a mixer (33) for injecting an injection signal from the local oscillator into the signal from the filter, where the frequency of the signal from the local oscillator is higher than the passband of the filter(32), thereby causing spectral inversion of the signal.

3. A radio device according to claim 1, where the device is a heterodyne receiver and comprises one or more stages, the or each stage comprising an asymmetric filtering element (11, 32) for providing a filtered signal centered around a centre frequency having greater rejection on a first side of the central frequency than on a second side, a local oscillator (31, 34) and a mixer (30, 33) for mixing a signal from the local oscillator with the filtered signal, wherein each local oscillator for each stage has a frequency which lies on the first side of the central frequency of the filtering element of that stage.

4. A radio device according to claim 1, where the radio stage comprises a preselector element (11) having a first centre frequency and greater rejection above the first centre frequency than below it and comprises a first local oscillator (31) and a first mixer (30) for mixing a signal from the first local oscillator with the signal from the preselector, where the first local oscillator has a frequency above the first centre frequency, thereby causing spectral inversion of the signal.

5. A radio device according to claim 4, further comprising an intermediate frequency stage between the radio stage and the baseband stage, where the intermediate frequency stage comprises a filter (32) having a second centre frequency and greater rejection below the second centre

frequency than above it and comprises a second local oscillator (34) and a second mixer (33) for mixing a signal from the second local oscillator with the signal from the filter, where the second local oscillator has a frequency below the second centre frequency.

6. A radio device according to any one of claims 2 to 5 wherein the digital signal processor (36) is arranged to demodulate the signal according to a modulation scheme having an asymmetric spectral shape.

7. A radio device according to claim 1, where the device is a transmitter and the digital signal processor (36) is arranged to provide a spectrally inverted baseband signal for passing to the radio stage for transmission by the radio stage and for spectral inversion prior to transmission

8. A radio device according to claim 7 wherein the digital signal processor is arranged to modulate the signal according to a modulation scheme having an asymmetric spectral shape.

9. A radio device according to claim 6 or claim 8, wherein the modulation scheme is a QAM mudulation scheme.

10. A radio device according to any one of the preceding claims, wherein the digital signal processor is arranged to compute the complex conjugate product of the signal.

Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report)** 9	Application number GB 9317317.7
Relevant Technical Fields (i) UK Cl (Ed.L) H3R: RMA, RMX, RAMX, RADC, RADX; H4P; PAQ (ii) Int Cl (Ed.5) H04L, H03D	Search Examiner MR S SATKURUNATH Date of completion of Search 1 DECEMBER 93
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASES: WPI, ECLA	Documents considered relevant following a search in respect of Claims :- 1-10

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
A	EP 0540195 A2 (FORD)	1
A	US 4893316 A (MOTOROLA)	1

Databases:The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).